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EFFECTS OF NATURAL FIBRES IN HIGH STRENGTH CONCRETE

T. Shanmugapriya*, K. Abirami, C. Manikanda**, S. Manivarman** & M. Manikandan****

* Assistant Professor, Department of Civil Engineering, Sri Ramakrishna Institute of Technology, Coimbatore, Tamilnadu

** UG Students, Department of Civil Engineering, Sri Ramakrishna Institute of Technology, Coimbatore, Tamilnadu

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Abstract:

Concrete is world's most widely used construction material. The utilization of concrete is increasing at a higher rate due to development in infrastructure and construction activities all around the world. The Reinforced Cement Concrete structures show distressing signs within a span of only 6 – 10 years, whereas, the standard life of Reinforced Cement Concrete frame structure is considered to be 60-80 years. This can be recognized by number of reasons like non-maintenance, changed usage arrangement or initial inferior quality of construction. The deficiency in tension can be defeated by the use of conventional rod reinforcement and to some extent by the inclusion of a sufficient volume of certain fibres. The use of natural fibres alters the behavior of fibre-matrix composite after it has cracked, thereby improving its toughness and have high impact strength besides having moderate tensile and flexural properties. In this study we are going to find the effects of natural fibres with 10 mix proportions in high strength concrete of M40 grade. The sisal, banana and coir fibres of aspect ratio 300 were added in plain concrete with the dosage of 0.5%, 1% and 1.5% respectively. Mechanical properties of these fibres were found by compression strength test for 7days and 28 days curing, split tensile strength test and flexural strength test for 28 days curing. The results of each fibre were compared and analyzed to find their effects in high strength concrete.

Key Words: Natural Fibres, Sisal Fibre, Banana Fibre, Coir Fibre & High Strength Concrete

1. Introduction:

The intensified research of the 1970's led to the development of commercially feasible, durable, modified-sulphur mortars, Concrete's versatility, durability, sustainability, and economy have made it the world's most widely used construction material. About four tons of concrete are produced per person per year worldwide and about 1.7 tons per person in the United States. The term concrete refers to a mixture of aggregates, usually sand, and either gravel or crushed stone, held together by a binder of cementitious paste. The paste is typically made up of Portland cement and water and may also contain supplementary cementing materials (SCMs), such as fly ash or slag cement, and chemical admixtures. Even though concrete is a widely accepted building material it is not without any drawbacks. The low tensile strength and brittle nature of concrete necessitates it to be reinforced with steel rods. Placing the steel reinforcement in the tension zone of concrete will enhance the tensile strength of concrete. Later on in 1960, it was found that addition of fibers in concrete can dramatically increase the various strength properties of concrete along with the ductility of concrete. For this purpose various fibers can be used in the concrete. The various fibres that are commonly used in concrete are steel, Galvanized Iron, polypropylene, glass, carbon, asbestos, jute plastic etc. The addition of fibers to concrete delays the failure mechanism and induces ductility to concrete. Such product where in the fibers are introduced in concrete is called "Fiber Reinforced Concrete" (FRC). Natural fibers are cheap and locally available in many countries. Fibers are a class of hair-like material that are continuous filaments or are in discrete elongated pieces, similar to pieces of thread. Natural fiber may be chemically more inert than either steel or glass fibers. They are also cheaper, especially if natural. A large volume of vegetable fiber may be used to obtain a multiple cracking composite. Natural fibres include coir, sisal, jute, Hibiscus cannabinus, eucalyptus grandis pulp, malva, ramie bast, pineapple leaf, kenafbast, sansevieria leaf, abaca leaf, vakka, date, bamboo, palm, banana, hemp, flax, cotton and sugarcane. In this project we are going to use sisal fibre, banana fibre and coir fibre. The objective of the project is to study the various properties of fresh concrete and hardened concrete with the addition of natural fibre in concrete and to evaluate the mechanical behavior of natural fibre in concrete with different percentage of fibre addition of various mixes.

2. Methodology:

The collection of previous data is studied on fibre reinforced concrete in the first stage of the project. Then after the collection of data, the grade of concrete M40 was selected for the project. Since the mix design for M40 grade are calculated and quantities are arrived for the material. For hardened concrete, the compressive strength test, split tensile strength test and flexural strength test are determined for various mix. After preparation of conventional concrete, addition of fibres such as sisal, banana and coir fibres are added into the concrete for various fibre dosages in different mixes. The concrete is casted into mould in the form of cubes of size 150mm x 150mm x 50mm, cylinders of size 300mm x 100mm and prism of size500mm x 100mm x 100mm at different mix proportions according to mix design for conventional concrete and fibre reinforced concrete. Then cubes, cylinders and prism are demoulded and laid in curing tank for 7 days and 28 days. After curing the cubes, cylinders and prism, the specimens are tested. Cubical specimens are tested for 7 days and 28 days to determine compressive strength. Cylindrical and beam specimens are tested for 28 days to determine split tensile strength and flexural strength for conventional and fibre reinforced concrete. Finally the results are compared with conventional concrete.

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3. Material and Its Properties:

The engineering structures are composed of materials. These materials are known as engineering materials or building materials or materials of construction. It is necessary for an engineer to become conversant with properties of such materials. Materials like cement, water, coarse aggregate and fine aggregate form the concrete mixture.

Cement: Cement is a binder, a substance used in construction that sets, hardens and adheres to other materials, binding them together. Cement is used to bind sand and gravel (aggregate) together. Cement is used with fine aggregate to produce mortar for masonry, or with sand and gravel aggregates to produce concrete. Portland Pozzolana Cement 53 grade is used. The cement commonly used is Portland cement. Cement is obtained by burning the mixture of calcareous and argillaceous materials at a very high temperature. The specific gravity of Portland Pozzolana Cement is 3.15.

Fine Aggregate: Fine aggregate are basically sands won from the land or the marine environment. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. The most important function of the fine aggregate is to assist in producing workability and uniformity in mixture. The action promotes plasticity in the mixture and prevents the possibility of segregation of paste and coarse aggregate particularly when it is necessary to transport the concrete some distance from the mixing plant to the point of placement. Specific gravity and water absorption of fine aggregate is 2.60 and 0.8%.

Coarse Aggregate: The coarse aggregate is the strongest and least porous component of concrete. Coarse aggregate in cement concrete contributes to the homogeneity of the cement concrete and there is a weak interface between cement matrix and aggregate surface in cement concrete. This results in lower strength of cement concrete by restricting the maximum size of aggregate and also by making the transition zone stronger. Coarse aggregate of size 20mm is used. Tests were conducted on coarse aggregate like specific gravity and water absorption. Specific gravity and water absorption of coarse aggregate is 2.72 and 1%

Water: Water was tested for pH value using pH meter and the value obtained was 7 to 7.4.

Natural Fibres: The chemical components like cellulose, hemi cellulose and lignin form the major composition in a plant fibre. Generally, the strength and stiffness of plant fibres depends on the cellulose content. Fibres were collected from the outside source: Tokyo Engineering Corporation, Coimbatore. Chemical composition of sisal fibre, banana fibre and coir fibre are given in Table 1.

Table 1: Chemical composition of sisal fibre, banana fibre and coir fibre METHODS

Chemicals	Sisal Fibre	Banana Fibre	Coir Fibre
Cellulose %	65	33	43.44
Hemicellulose %	12	17	0.25
Lignin %	9.9	15	45.84

4. Concrete Mix Design & Testing Methods:

Mix design is known as the process of selecting suitable ingredients of concrete and determining their relative proportions with object of producing concrete of certain minimum strength and durability as economically as possible. Mix design for M40 grade of concrete was done as per IS code 10626:2009 and IS 456:2000 for extreme exposure condition. Quantity of cement, coarse aggregate, fine aggregate and water were found out for one cubic meter of concrete. Mix proportioning was done and mix ratio was found.

Mix Proportion:

Cement = 492.5 kg/m³
Water = 197lit/m³
Fine aggregate = 713.25 kg/m³
Coarse aggregate = 1020.70 kg/m³
Water cement ratio = 0.40

Mix Proportion Ratio:

Cement : Fine aggregate : Coarse aggregate
1 : 1.43 : 2.07

Three natural fibres namely, sisal, banana and coir are used in this project. Their diameter was found to be 0.18mm, 0.114mm and 0.08mm. Aspect Ratio of 300 was chosen. By using the aspect ratio and diameter of the fibres, length of fibres to be laid in concrete was found. Three percentages of fibre dosage, 0.5%, 1% and 1.5% were chosen and their quantities are estimated by volume of cement for each mix. The mix identity is presented in Table 2.

Table 3: Slump Cone Test Results

Mix ID	Slump Values (MM)
M1	90
M2	101
M3	105
M4	110
M5	103
M6	106
M7	115

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M8	101
M9	108
M10	112

5. Test on High Strength Concrete:

Test on Fresh Concrete: Fresh concrete test is done to check workability of concrete either in laboratory or at site.

Slump Cone Test: The slump test is the most well-known and widely used test method to characterize the workability of fresh concrete. The apparatus consists of a mould in the shape of a frustum of a cone with a base diameter of 200 mm, a top diameter of 100mm and a height of 300mm. The pattern of slump indicates the characteristics of concrete in addition to the slump value.

Test on Hardened Concrete: Hardened concrete test are done to find the strength of the concrete at the end of 7^{th} day and 28^{th} day curing of the specimens. Hardened concrete test are, Compressive Strength Test, Split Tensile Strength Test, Flexural Strength Test.

Compressive Strength Test: All the cubes were tested in compressive testing machine to determine the compressive strength of the cubes. The procedure is as follows. Place the specimen centrally on the location marks of the compression testing machine. Load is applied continuously, uniformly and without shock. Record the maximum load applied to the specimen. Compressive strength is calculated by the following formula,

Compressive strength = P/A (N/mm^2)

Where, P = compressive load on the cylinder

A = cross sectional area of the cylinder

Split Tensile Strength Test: Three cylindrical specimens were prepared. Place the specimen on the plywood strip and align so that the lines marked on the ends of the specimen are vertical and centered over the plywood strip. Place the second plywood strip lengthwise on the cylinder, centered on the lines marked on the ends of the cylinder. The load is applied without shock and increases it continuously at a rate to produce a split tensile stress. Record the maximum load indicated by the testing machine at failure. Split tensile strength is calculated using the following formula,

Split tensile strength = $2P/\pi LD$ (N/mm2)

Where,

P is the compressive load on the cylinder.

L is length of the cylinder.

D is the diameter of the cylinder.

Flexural Strength Test: All the beams will be tested in flexural strength testing machine. The dimension of each specimen is noted before testing. The specimen is then placed in the machine in such manner that load is applied to the upper most surface as cast in the mould. The axis of specimen is carefully aligned with the axis of the loading device. The load is applied without shock and increasing continuously at a rate of the specimen. The load is increased until the specimen fails and the maximum load applied to the specimen during the test is recorded.

Flexural Strength = PL/bd^2

Where,

fb = Modulus of rupture in N/mm^2.

P = Maximum load applied on the specimen.

L = Length of the span on which specimen is support.

b = Width of the specimen.

6. Result and Discussion:

Fresh Concrete:

Slump Cone Test: The workability of concrete is determined by slump cone test . The slump cone values are given in Table 3 and Figure 1.

Table 3: Slump Cone Test Results

Mix ID	Slump values (mm)
M1	90
M2	101
M3	105
M4	110
M5	103
M6	106
M7	115
M8	101
M9	108
M10	112

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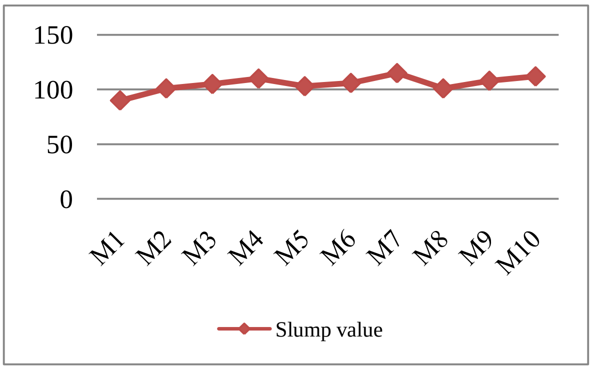

Figure 1: Comparison of compressive strength for sisal fibre, banana fibre and coir fibre concrete with conventional concrete

From the above table and figure the slump cone values are increases which denote the high workable in nature. As compared to conventional concrete, slump value of fibre reinforced concrete increases for each percentage of fibre dosage.

Hardened Concrete: Concrete that is in a solid state and has developed certain strength. The reaction continuous with time as it produces hard, strong and durable solid material.

Compressive Strength Test: Compressive strength was determined at the age of 7 and 28 days for testing of specimens. Average compressive strength for various mixes is compared in figure 2(a), (b) & (c). Average compressive strength for various mixes are tabulated in Table 4.

Table 4: Average compressive strength Test Results

Mix	Fibre Dosage %	Average compressive strength in N/mm²	
		7 days	28days
M1	0	28.41	46.5
M2	0.5	28.3	46.66
M3	1	29.56	48.26
M4	1.5	25.48	40.29
M5	0.5	28.6	47.26
M6	1	29.78	49.76
M7	1.5	23.70	37.92
M8	0.5	28.40	48.74
M9	1	24.29	41.33
M10	1.5	21.48	38.54

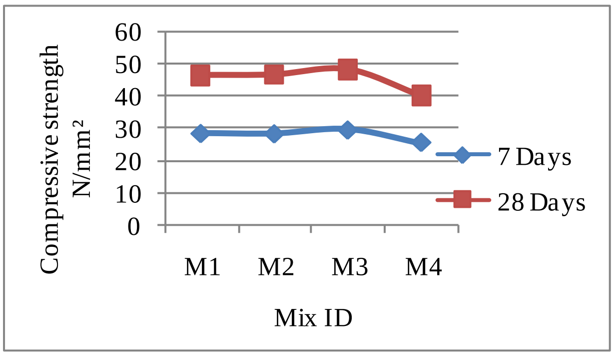

Figure 2(a): Comparison of compressive strength for sisal fibre

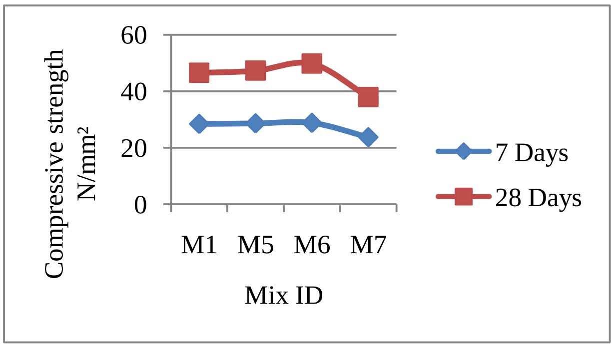

Figure 2(b): Comparison of compressive strength for banana fibre

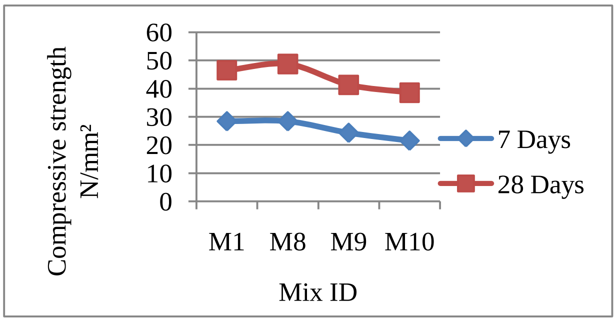

Figure 2(c): Comparison of compressive strength for coir fibre

The increase in compressive strength for sisal fibre concrete was 5.04% (7 days) and 5.93% (28 days), for banana fibre concrete 5.82% (7 days) and 7.01% (28 days), for coir fibre 0.92% (7 days) and 4.81% (28 days), this increase in compressive strength due to reduction of voids by presence of fibres. There is a decrease in strength due to excess amount of fibre content. It will reduce the workability and decrease cohesiveness. Also absorb certain amount of water content.

Split Tensile Strength Test: Average split tensile strength for various mixes are tabulated in table 5

Table 5: Average Split Tensile Strength Test Results

Mix	Fibre dosage %	Average split tensile strength in N/mm² At 28 days
M1	2	4.24
M2	0.5	4.33
M3	1	4.92
M4	1.5	3.53
M5	0.5	4.43
M6	1	4.49
M7	1.5	3.86
M8	0.5	4.38
M9	1	3.35
M10	1.5	3.31

Average split tensile strength for various mixes are compared in figure 3(a), (b) &(c).

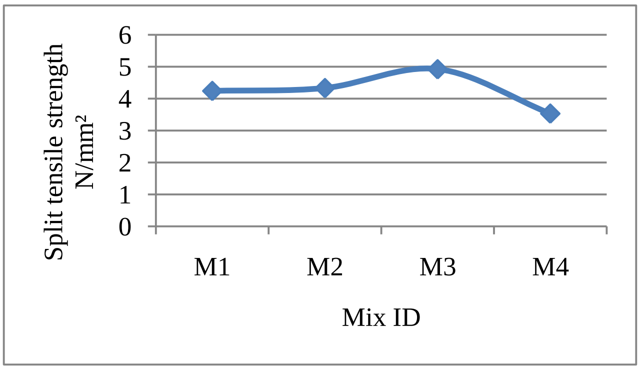

Figure 3(a): Comparison of split tensile strength for sisal fibre

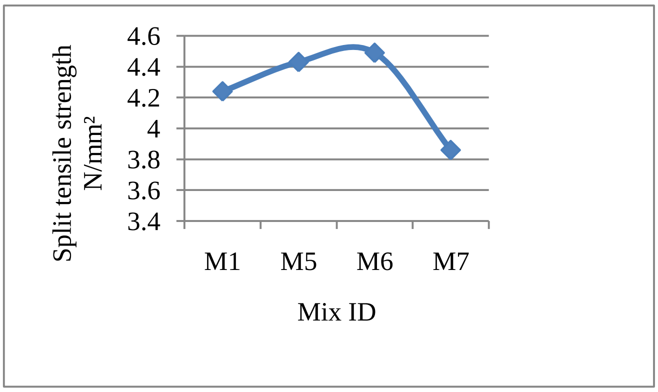

Figure 3(b): Comparison of split tensile strength for banana fibre

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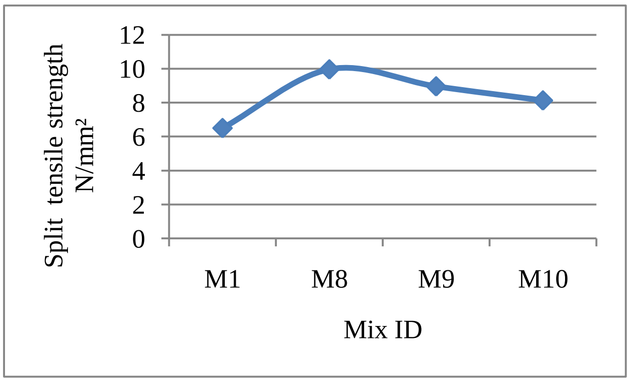

Figure 3(c): Comparison of split tensile strength for coir fibre

From the above Figure 3(a), (b) &(c), the test results the split tensile strength of conventional concrete and fibre reinforced concrete for 28 days curing are discussed here. It was found that mix M3 (1% dosage sisal fibre) achieved the highest tensile strength of 16.03%. Whereas, mix M6 (1% dosage of banana fibre) and mix M8 (0.5% dosage coir fibre) achieved the tensile strength of 5.8% and 3.3% when compared to conventional concrete mix M1.

Flexural Strength Test: Flexural strength is one measure of the tensile strength of the concrete. Average flexural strength for various mixes are tabulated in Table 6

Table 6: Average Flexural Strength Test Results

Mix ID	Fibre dosage %	Average flexural strength in N/mm² At 28 days
M1	0	6.5
M2	0.5	9.19
M3	1	11.29
M4	1.5	8.08
M5	0.5	9.79
M6	1	10.96
M7	1.5	9.96
M8	0.5	9.96
M9	1	8.96
M10	1.5	8.13

Average flexural strength for various mixes are compared in figure 4(a), (b) & (c).

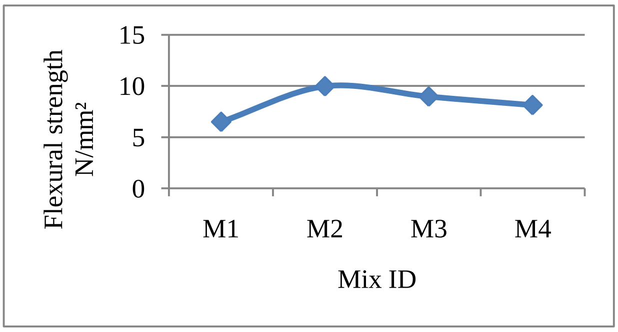

Figure 4(a): Comparison of flexural strength for sisal fibre

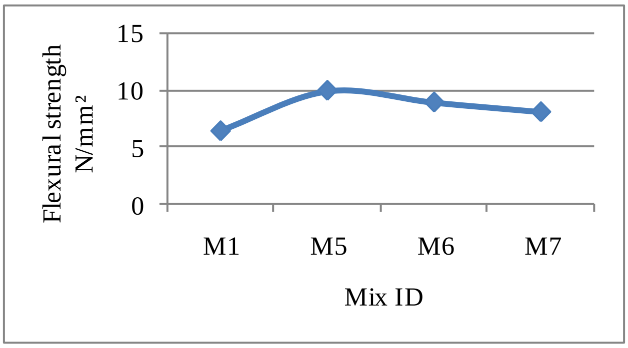

Figure 4(b): Comparison of flexural strength for banana fibre

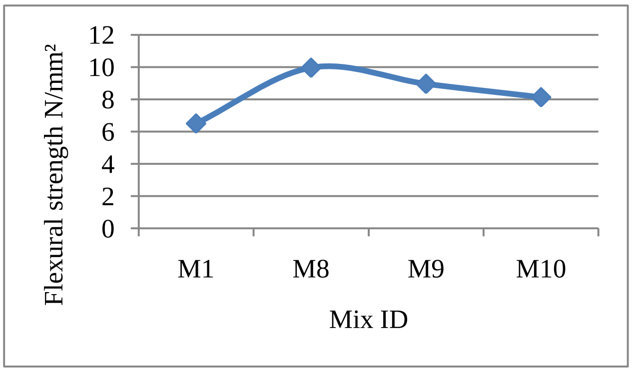

Figure 4(c): Comparison of flexural strength for coir fibre

From the above Figures the test results for the flexural strength of conventional concrete and fibre reinforced concrete for 28 days curing are discussed here. It was found that mix M3 (1% dosage sisal fibre) achieved the highest flexural strength of 73%. Whereas, mix M6 (1% dosage banana fibre) and mix M8 (0.5% dosage coir fibre) achieved the flexural strength of 68.6% and 53% when compared to conventional concrete mix M1.

7. Conclusion:

The following conclusions can be draw from the results presented in this study.

- ✓ The compressive strength of the conventional concrete when compared to natural fibre reinforced concrete at the end of7^{th}day and 28^{th} day was increased by 5.04% and 5.93 in sisal fibre (1% dosage), 5.82% and 7.01% in banana fibre (1% dosage) and 0.92% and 4.81% in coir fibre (0.5% dosage).
- ✓ The split tensile strength of the conventional concrete when compared to natural fibre reinforced concrete at the end of 28^{th} day was increased by 16.03% in sisal fibre (1% dosage), 5.8% in banana fibre (1% dosage) and 3.3% in coir fibre (0.5% dosage).
- ✓ The flexural strength of the conventional concrete when compared to natural fibre reinforced concrete at the end 28^{th} day was increased by 73% in sisal fibre (1% dosage), 68% in banana fibre (1% dosage) and 53% in coir fibre (0.5% dosage).

Thus, it was concluded that 1% addition of banana fibre gives good compressive strength, 1% of sisal fibre gives better tensile strength and 1% of sisal fibre and banana fibre and gives better flexural strength.

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